

Tidal thickening of galaxy disks

Vladimir Reshetnikov^{1,2}, Francoise Combes²

¹ Astronomical Institute of St.Petersburg State University, St.Petersburg, Russia

² DEMIRM, Observatoire de Paris, 61 Av. de l'Observatoire, F-75014 Paris, France

Abstract. We have studied a sample of 24 edge-on interacting galaxies and compared them to edge-on isolated galaxies, to investigate the effects of tidal interaction on disk thickening. We found that the ratio h/z_0 of the radial exponential scalelength h to the scale height z_0 is about twice smaller for interacting galaxies. This is found to be due both to a thickening of the plane, and to a radial stripping or shrinking of the stellar disk. If we believe that any galaxy experienced a tidal interaction in the past, we must conclude that continuous gas accretion and subsequent star formation can bring back the ratio h/z_0 to higher values, in a time scale of 1 Gyr.

1 Motivation

Galaxy disks are very sensitive to tidal interactions, from the formation of tidal tails and bridges up to the complete disruption of initial disks in mergers. Even non-merging interactions or minor mergers can thicken and destroy a stellar disk, and this has been advanced as an argument against frequent interactions in a galaxy life, or formation of the bulge through minor mergers in spiral galaxies.

Toth & Ostriker (1992) have used the argument of the fragility of disks to constrain the frequency of merging and the amount of accretion, and draw implications on cosmological parameters. They claim that the thickness of the Milky Way disk implies that no more than 4% of its mass can have accreted within the last $5 \cdot 10^9$ yrs; moreover they question the currently fashionable theory of structure growth by hierarchical merging, which would not be supported by the presence of thin galactic disks, cold enough for spiral waves to develop.

2 Sample and observations

Our sample consists of 24 interacting systems containing at least one edge-on galaxy. We also observed a control sample of 7 edge-on isolated galaxies for comparison.

Observations were carried out at the OHP 1.2 m telescope in the B , V and I passbands. General photometric results of the observations (including isophotal maps of all objects) are presented in Paper I.

3 Results

For most galaxies, we find a constant scale height with radius, within 20%.

From the direct comparison of scale height z_0 and h/z_0 distributions in both samples of interacting and isolated spirals we find evidence for **thickening** of galactic disks in interacting systems, **by a factor 1.5 to 2** (see Fig.1). This thickening refers to the region of exponential disk between 1 and 2.4 of exponential scalelength (or between 0.6 and 1.4 of effective radius).

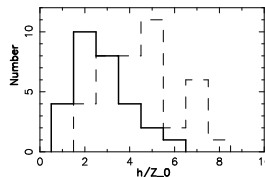


Fig. 1. Distribution of scalelength to scale height ratios for interacting (thick solid line) and normal (dashed line) galaxies. The data for normal spirals are from our observations and literature.

The mean characteristics of edge-on interacting galaxies in our sample are: absolute blue luminosity $M_B = -19.6 \pm 1.0$ (so “face-on” magnitude must be about -21), exponential scalelength $h = 4 \pm 2$ kpc ($H_0 = 75$ km/s/Mpc). Therefore, the typical galaxy in our sample is comparable with the Galaxy and M 31. Most edge-on galaxies in the interacting sample have comparable luminosity companions within one optical diameter.

One can conclude that tidal interaction between large spiral galaxies, like the Milky Way and the Andromeda galaxy, at a relative distance of about one optical diameter, leads to thickening by a factor 1.5-2 of their stellar disk.

4 Discussion

The h/z_0 ratio is 1.5-2 times smaller in interacting galaxies: this is found to be due not only to a higher average scale height z_0 in the interacting sample, but also to a somewhat smaller scalelength h .

This corresponds quite well to the predictions of N-body simulations (Quinn et al 1993, Walker et al 1996): the gravity torques induced by the tidal interaction produce a central mass concentration, while the outer disk spreads out radially, leading to a decrease of h . Most of the heating is expected to be vertical, since the planar heating is taken away by the stripped stars either in the primary or in the satellite. The quantitative agreement between observations and simulations is rather good, given the large dispersion expected due to the initial morphology of the interacting galaxies: a dense satellite will produce much more heating than a diffuse one, where stripped stars take the orbital energy away; a mass-condensed primary will inhibit tidally-induced spiral and bar perturbations, that are the source of heating both radially and vertically.

The fact that tidal interactions and minor mergers must have concerned every galaxy in a Hubble time, and therefore also the presently isolated and

undisturbed galaxies, tells us that the lower values of h/z_0 observed for the interacting sample must be transient. Radial gas inflow induced by the interaction may have contributed to **reform a thin young stellar disk**, while the vertical thickening has formed the thick disk components now observed in the Milky Way and many nearby galaxies. This process might be **occurring all along the interaction**, so that the galaxy is never observed without a thin disk. One cannot therefore date back the period of the last interaction by the age of the thin disk, as has been proposed by Toth & Ostriker (1992) and Quinn et al (1993). The Milky Way, experiencing now interactions with the Magellanic Clouds and a few dwarf spheroidal companions, has still a substantial gaseous and stellar thin disk. Further self-consistent simulations, including gas and star-formation, must be performed to derive more significant predictions.

The fundamental role of the re-formation of a thin stellar disk is obvious in Fig.2: there are correlations between the HI content of a galaxy and its stellar scale height and relative thickness h/z_0 . Dashed lines in Fig.2 show double regression fits for normal spirals: z_0 (kpc) = $0.84 \times [M(\text{HI})/L_B]^{-1/2}$ and $h/z_0 = 5.0 \times [M(\text{HI})/L_B]^{1/2}$, where $M(\text{HI})$ is the total HI mass (in M_\odot) and L_B is the total luminosity of the edge-on galaxy (in L_B^\odot) uncorrected for internal absorption. Interacting galaxies in general follow the same relations as normal spirals but with larger scatter. It is interesting that the Milky Way is also satisfying the above relations. Adopting for the absolute luminosity of "edge-on" Milky Way $M_B \approx -20.5 + 1.5 = -19.0$ and $M(\text{HI}) = 8 \cdot 10^9 M_\odot$, we obtain from the above correlations $z_0 = 0.74 \pm 0.27$ kpc and $h/z_0 = 5.7 \pm 1.7$. These values are in agreement with current estimates of the Milky Way parameters (e.g. Sackett 1997).

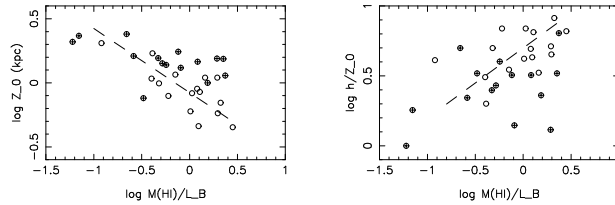


Fig. 2. Distribution of normal (open circles) and interacting (solid circles) galaxies in the plane $M(\text{HI})/L_B - z_0$ (left) and $M(\text{HI})/L_B - h/z_0$ (right).

References

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